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NOTES ON GEOGRAPHIC DISTRIBUTION

New data on the distribution of *Torodinium robustum* and *T. teredo* (Dinophyceae: Gymnodiniales) in the Gulf of California

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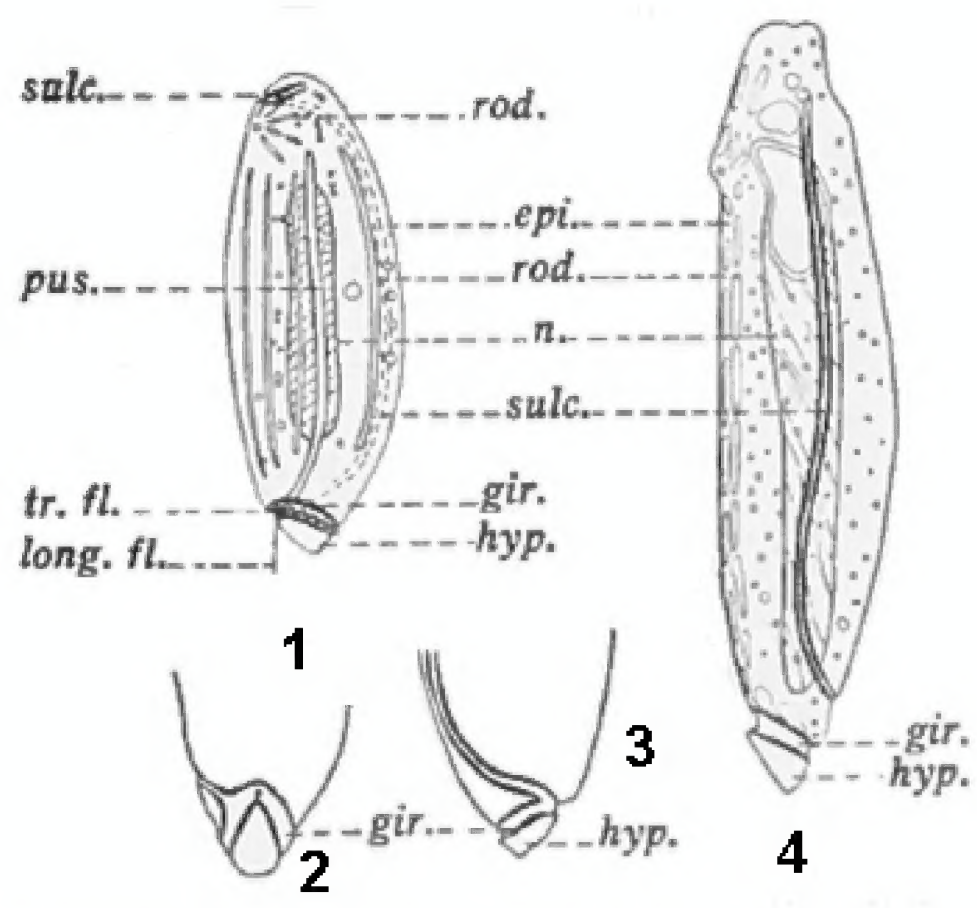
ABSTRACT: The gymnodinioid marine dinoflagellates *Torodinium robustum* and *T. teredo* are reported for the Gulf of California. This is the first record of *Torodinium teredo* on the Pacific coast of Mexico. Both species were found mainly during the winter-spring in seawater at 19–27.5 °C. *Torodinium robustum* was the most frequent species. Morphological features of *T. robustum* and *T. teredo* varied widely and specimens observed in live samples and fixed in Lugol's solution were easily recognizable. Short description and microphotographs were provided for each species.

The unarmored dinoflagellates of the order Gymnodiniales Lemmermann, 1910 lack cellulose plates, but have a membranous outer covering of small vesicles. Most of the studies of gymnodinioid dinoflagellates in Mexico have focused on the bloom forming species, which are common in coastal waters like *Akashiwo sanguinea* (K.Hirasaka) G.Hansen and Ø.Moestrup 2000, *Amphidinium carterae* Hulburt, 1957, *Cochlodinium fulvescens* Iwataki, Kawami and Matsuoka, 2008, *Cochlodinium polykrikoides* Margalef, 1963, *Gymnodinium catenatum* Graham, 1943, *Gyrodinium instriatum* Freudenthal and Lee, 1963, and *Katodinium glaucum* (Lebour) Loeblich III, 1965 (Cortés-Altamirano 1998; Gárate-Lizárraga *et al*. 2004; 2006; 2009; Morquecho-Escamilla and Alonso-Rodríguez. 2008; Gárate-Lizárraga; 2012; 2013). The genus *Torodinium* Kofoid and Swezy 1921 with two taxonomically accepted species (Brandt 2010; 2011), *Torodinium robustum* Kofoid and Swezy, 1921 and *T. teredo* (Pouchet) Kofoid and Swezy, 1921 belongs to the order Gymnodiniales and family Gymnodiniaceae. *Torodinium* species are characterized by a very large episome that occupies most of the cell body, a posterior cingulum, a much-reduced hyposome, and the sulcus extending along the episome only (Kofoid and Swezy 1921). Main morphological and taxonomical features are shown in Figures 1–4. *Torodinium* species are marine planktonic dinoflagellates, free-living, unicellular, and apparently cosmopolitan (Gómez 2009; Hoppenrath *et al*. 2010). Along the Mexican coast of the Pacific, *T. robustum* has rarely been reported (Gaxiola-Castro *et al*. 1987; Morquecho-Escamilla and Lechuga-Devéze 2004; Gárate-Lizárraga *et al*. 2009). This report confirms the presence of *Torodinium robustum* and registers for the first time *T. teredo* at some sites in the Gulf of California. Information about their morphology and ecology is also provided.

Phytoplankton samples were collected at three sites: (1) off Petroléos dock in the shallow basin of the southernmost region of the Bahía de La Paz; (2) Cuenca Alfonso in Bahía de La Paz and (3) off Los Cabos with four sampling stations (Figure 5). Geographic coordinates for each sampling station are shown in Table 1. From January 2009 to April 2012, 42 collections of phytoplankton were taken at the first sampling station (Figure 5). Surface and vertical (15 m depth) phytoplankton tows were collected with a 50 cm diameter 20 µm mesh net. Each net tow was immediately preserved with acid Lugol's solution (5% final concentration). Subsamples were taken for observations of live phytoplankton. From February through December 2010, 19 vertical net hauls were monthly taken from 60 m depth at the second sampling station in the northern part of Bahía de La Paz. In July 2010 at Los Cabos, 4 vertical net hauls were conducted from 15 m depth to



FIGURES 1-4. *Torodinium* species diagram taken from Kofoid and Swezy (1921). (1) *Torodinium robustum*. Left lateral view. (2) Ventral view of antapical region. (3) Right lateral view of antapical region of the same figure. (4) *Torodinium teredo*. Abbreviations: epi., epicone; (gir., girdle or cingulum; hyp., hypocone; long fl., longitudinal flagellum; n., nucleus; pus., pusule; rod., rodlets or rhabdosomes; sulc., sulcus; tr. fl., transverse flagellum.

the surface at Stations 3, 4, 5 and 6 (Figure 5). Cell counts were made in 5 mL settling chambers under a Carl Zeiss inverted microscope (Hasle 1978). Both live and fixed net phytoplankton samples were analyzed by phase contrast microscopy. Sea surface temperature (SST) was recorded with a bucket thermometer. Images were recorded (SONY Cyber-shot camera, 8.1 MP) under a Carl Zeiss inverted microscope.

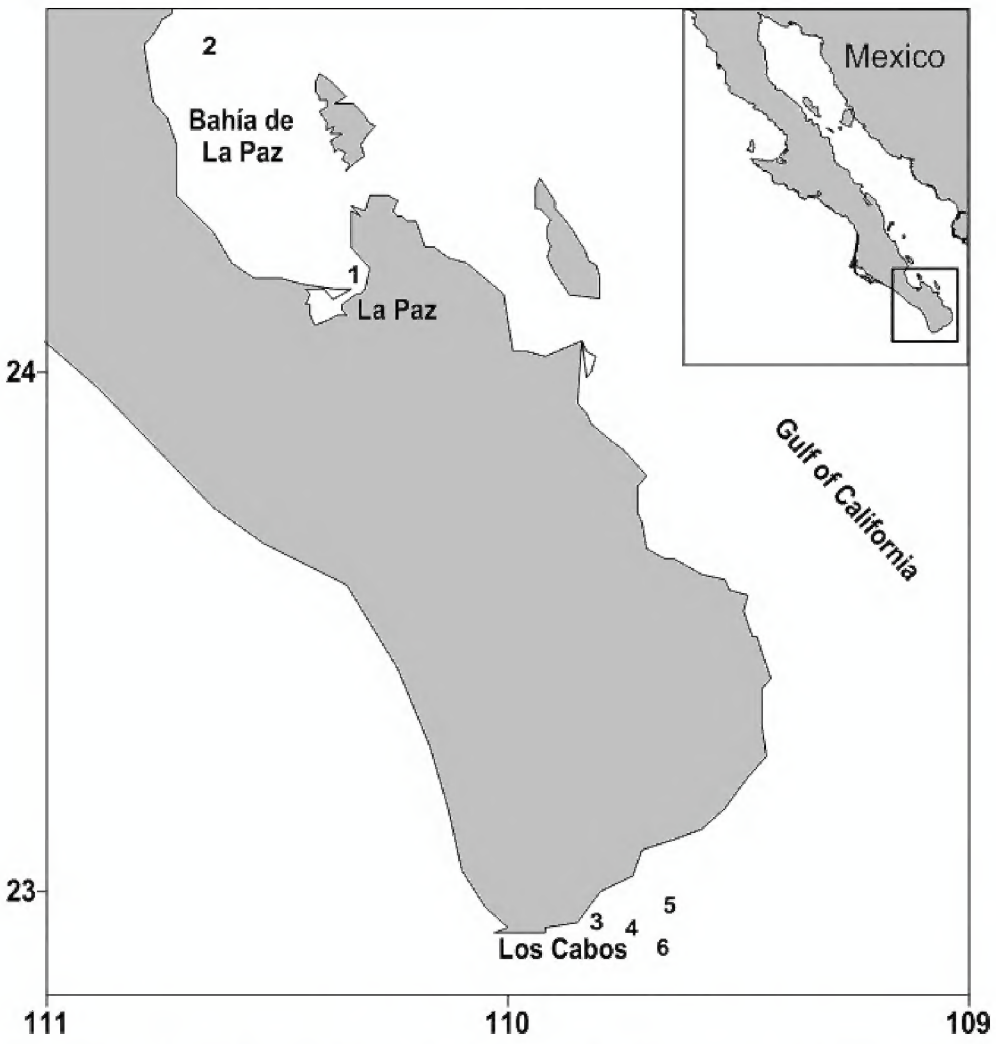


Figure 5. Sampling stations in Bahía de La Paz, and Los Cabos at the southern end of the Baja California Peninsula.

Two *Torodinium* species were identified in the samples collected monthly from Bahía de La Paz from January 2009 to April 2012 and in samples of July 2010 collected at Los Cabos. Specimens of both species fit well with the diagnosis and descriptions of Kofoid and Swezy (1921). All samples containing *Torodinium* species were listed in Table 1. A total of 167 specimens of *T. robustum* were observed only in net phytoplankton hauls at the three sampling sites in this study (Table 1). Therefore, no quantitative data are presented, however, densities from 1000 to 45000 cells L^{-1} were reported during a multi-species red tide event (Gárate-Lizárraga *et al*. 2009). This species occurred in seawater with temperature of 19.0–27.5 °C. *T. robustum* cells have an elongated body with a very small hypocone, reduced to a conical structure (Figure 2). Cell length is less than 3.5 greatest transdiameters, the sulcus has a reversed terminal apical loop, and the girdle forms a left-handed spiral (Figures 6–11). Cells are about 60–75 µm (69.63±2.95 µm) long and 20–37.5 µm (28±3.81 µm) wide (n = 30). In Figure 9 the *T. robustum* is 60 µm long and 37.5 µm wide. The nucleus is an elongated rod with rounded end located centrally. A very long and small pusule extended to nearly the same point as the nucleus. Many greenish to brown chloroplasts, arranged into longitudinal rows, are present (Figures 6–11).

Torodinium robustum is a planktonic species which has been found at Burnham (Essex) and Plymouth in the United Kingdom. It has been reported in the North Sea, Mediterranean Sea, and the Pacific (Kofoid and Swezy 1921; Lebour 1925; Trégouboff and Rose 1957). Some specimens from NW Africa are related with upwellings (Elbrächter 1979). More recently, *T. robustum* has been reported at La Jolla, California (Kimor and Reid 1989), in Japan (Yoshimatsu 1990), in the Helgoland and Sylt islands in the North Sea (Hoppenrath *et al*. 2009), and in Kuwait (Al-Kandari *et al*. 2009).

A total of 93 specimens of *T. teredo* were indentified only in net phytoplankton hauls at sampling station 1 (Table 1). This species occurred in seawater with temperature of 19.0–24.5°C. *T. teredo* cells have a very elongated body (Figures 12–14). Cell length is more than 4 transdiameters; there is no loop in the terminal part of the sulcus. The epicone is very long and the hypocone is reduced to a conical structure. The sulcus arises near the apex of the cell with a loop nearly completely around the cell and then curves to meet the girdle. The nucleus is elongated and located along the centre of the cell. Cells are about 100–115 µm (108.67±4.40 µm) long and 20–27.5 µm (24.43±2.04 µm) wide (n = 30). Gómez (2009) found that *T. teredo* specimens had an elongated protuberance, a peduncle that protrudes from the sulcal-cingular region.

Figures 6-14. Microphotographs of *Torodinium* species from the southwestern Gulf of California. Figs. 6, 7, 8, and 9: live specimens of *Torodinium robustum* collected in June 2008, March 2009, June 2010, February 2011 respectively, in Bahía de La Paz. Fig. 10 and Fig. 11: Lugol-fixed specimen of *Torodinium robustum* collected in May 2010 at Cuenca Alfonso and in July 2010 at Los Cabos, respectively. Figs. 12 and13: Live specimens of *Torodinium teredo* collected in Bahía de La Paz in March 2009 and April 2011, respectively. Fig. 14: Lugol-fixed specimen of *Torodinium teredo* collected in October 2010 at Cuenca Alfonso.

Table 1. Geographic coordinates for each station, sampling date, number of specimens of *Torodinium robustum* and *Torodinium teredo* and SST data recorded in 17 field samplings performed at Bahía de La Paz and Los Cabos.

SAMPLING STATION	LATITUDE (N)	LONGITUDE (W)	DATE (D/M/Y)	SURFACE NET SAMPLES	VERTICAL NET SAMPLES	SST (°C)
1	24° 21’	110°31’	23/01/09	*T. robustum* (4)	*T. robustum* (6)	20
1			19/02/09	*T. robustum* (8)	*T. robustum* (2)	21
1			26/02/09	*T. teredo* (5)	*T. robustum* (13)	21
1			05/03/09	*T. teredo* (6)	*T. teredo* (7)	22
1			17/03/09	*T. teredo* (11)		22.5
1			24/06/10	*T. robustum* (16)	*T. robustum* (17) *T. teredo* (5)	25
1			13/12/10	*T. teredo* (3)	*T. robustum* (14) *T. teredo* (9)	21
1			23/01/11	*T. teredo* (18) *T. robustum* (6)	*T. robustum* (21) *T. teredo* (2)	23.5
1			17/02/11	*T. teredo* (5) *T. robustum* (7)	*T. robustum* (8) *T. teredo* (14)	19
1			28/04/11	*T. robustum* (4)	*T. robustum* (7)	23
1			24/02/12	*T. robustum* (2)		
1			19/04/12	*T. robustum* (2)		24.
2	24° 39’	110°36’	01/02/10		*T. robustum* (4)	21.5
2			01/05/10		*T. robustum* (2) *T. teredo* (1)	24.5
2			16/10/10		*T. teredo* (2) *T. robustum* (2)	27
2			23/01/11		*T. robustum* (3)	24
3	22° 55’	109° 47’	01/07/10	*T. robustum* (3) *T. teredo* (4)		24.5
4	22° 52’	109° 45’	01/07/10	*T. robustum* (2)		25.0
5	22° 51’	109° 31’	01/07/10	*T. robustum* (5)		27.5
6	22° 48’	109° 40’	01/07/10	*T. robustum* (9) *T. teredo* (1)		27.3

This peduncle was not observed in live or fixed cells in our samples.

Torodinium teredo is a planktonic species, apparently widely distributed in temperate and tropical waters; it has been reported from several locations in the North Sea, English Channel, Mediterranean Sea, Pacific Ocean, and Gulf of Mexico (Kofoid and Swezy 1921; Lebour 1925, Trégouboff and Rose 1957; Steidinger *et al.* 1967). In northwestern Africa *T. teredo* is related with water upwelling (Elbrächter 1979) and recently it was reported in several regions of the open Pacific Ocean: Oyashio and Kuroshio currents of East Asia, The Philippines, Celebes, Sulu, South China Sea, western and central equatorial Pacific, subtropical Pacific in the vicinity of the Marquesas Archipelago, in the South Pacific Gyre, and in the Perú-Chile Current (Gómez 2009) and the European Arctic (Okolodkov 2011). *Torodinium teredo* is now reported for the first time in the Gulf of California in Pacific waters of Mexico.

Torodinium teredo and *T. robustum* occur together in the North Sea, Mediterranean Sea and Gulf of California (Lebour 1925; Trégouboff and Rose 1957; this study). The species were easily recognized in live samples as well as samples fixed in Lugol’s solution. *T. teredo* is easily distinguished from *T. robustum* because its length is more than four transdiameters, no loop is observed in the terminal part of the sulcus, the larger size, and the green pigmentation (Pouchet 1885; Kofoid and Swezy 1921; Steidinger and Tangen 1997; this study). Despite the morphological characteristics to distinguish both species, their ultrastructural morphology and DNA sequences should be examined more carefully once they could possibly increase the distinction between the species.

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